Motorola's silent, desk top, non-impact, all electronic, low-cost teleprinter . . . .

HALF SIZE & FULL SOUND

A typewriter-size, all-electronic page printer, in combination with an advanced solid state translator featuring core-rope memory and integrated logic circuitry, may soon be helping to solve your data retrieval and processing problems, providing instantaneous readout of data from time-shared computer and communications networks. High speed to match modern computer data rates, a significant economic advantage over present-day 100 wpm printers, and unparalleled flexibility in code-to-code conversion, are some of the reasons why. Edward Shainer, Manager, Teleprinter Programs at Motorola's Chicago Center, examines the code translation requirements for a modern data terminal, and shows how the TP-4000 Teleprinter is expressly designed to answer them.

The mushrooming computer and management information utilities are pressing demands for flexible, low cost terminals capable of communicating with central processors over the common carrier networks. Of these data terminal requirements, one of the most difficult to fulfill has been the printer. Although the time charges for a 3000-word per minute data communication channel are about 2½ times the charge for a comparable 100 wpm circuit, when computed on a cost-per-word or message basis, the cost of the higher speed service is about one-twelfth of the low speed service.

Those concerned with transmission of voluminous data quite naturally want to take advantage of this lower cost and the 30 times faster data rate. However, the problem has been that although suitable 100 wpm printers have been available in the $2,000 to $4,000 range, one had to be prepared to pay $10,000 and up for a high-speed printer. This differential becomes significant when the system requires tens and often hundreds of terminals. The Motorola TP-4000 teleprinter now provides a solution of the data communications terminal problem because it provides:

High Speed — 3000 word per minute printing speeds which is the limit of the voice grade communication facility.

Low Cost — Significant cost advantage over existing competitive printers.

Quiet — Smooth, continuous, non-impact motions provide noiseless operation.

Small Size — Smaller than a typewriter.

Flexible — Accommodates wide range of data rates and input codes.

Immediate Copy — Permanent copy immediately available without further processing.

Motorola has been supplying printers for a wide variety of data communication applications. Various models have been produced for mobile, airborne, shipboard, military and commercial requirements. The AN/AGC-3 is one model provided for airborne applications. The TT-352/FYQ-4 and TT-414/FYQ are the desk top and rack mounted teleprinters used throughout the 465L Strategic Air Command Control System. The TP-3000, which satisfies a wide range of military specifications, is a desk top printer that is used by many military, governmental and demanding commercial applications. [1, 2] The TP-4000 is a low cost commercial printer designed for computer peripheral and communication network applications.[3] Described here are the code translation techniques which contribute to the versatility and low cost of the TP-4000. In addition, we will describe other inherent, code translating features which contribute to the desirability of the TP-4000 as a widely used data terminal. The mechanics of the printing process, which have been described in previous articles, are repeated only to the extent necessary to clarify the requirements of the translator.

ALL-ELECTRONIC TP-4000 TELEPRINTER

The TP-4000 teleprinter functions similar to a typewriter in that it accepts and prints characters serially. Beyond that however, there can be no comparison, because all present Motorola teleprinters employ electronic, non-impact techniques which easily provide printing speeds up to 3000 wpm.

Common to all present Motorola printers is a time-proven facsimile printing process whereby an electric pulse, applied to a stylus in contact with the paper, causes a change to take place on the papers' surface in the form of a dark dot. Thus, various graphical patterns may be formed by controlling the sequence of electrical pulses as the stylus traverses the surface of the paper. The patented Motorola technique provides increased speed of the facsimile process by arranging seven styli in a vertical fashion. As the print head, composed of seven vertically mounted styli, is moved from left to right across the paper

in a smooth, continuous fashion, it receives five sequential sets of seven parallel pulses to form a 7x5 dot matrix. The character is formed by selection of a particular combination of the 35 dots in the matrix.

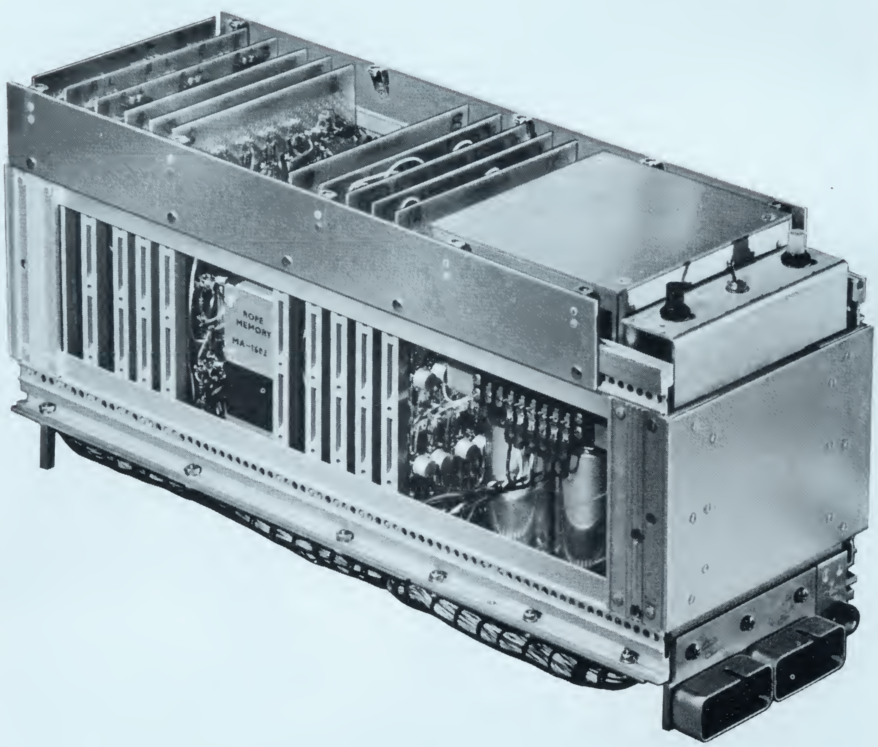
As shown in Figure 1, the smooth continuous motion of the print head and paper supply is provided by mounting four print heads on an endless sprocket driven belt which is inclined upward to the right. In addition to providing continuous motions, the placement of four print heads, spaced slightly more than one line length on an endless belt, reduces the frequency of replacement. The paper is fed continuously in synchronism with the print heads by wrapping it around a small drum which is driven through a gear meshed with the print belt sprocket drive. Thus, the combination of a continuously fed paper and the continuous scan of the print heads at an incline upward to the right provides a horizontal line of serially printed characters. This simple mechanism is coupled to a synchronous motor through a solenoid operated clutch. In the de-energized state, the clutch provides registration for the left margin; during standby, it inhibits all mechanical motions except the continuously running ball bearing motor.

BASIC TRANSLATOR REQUIREMENTS

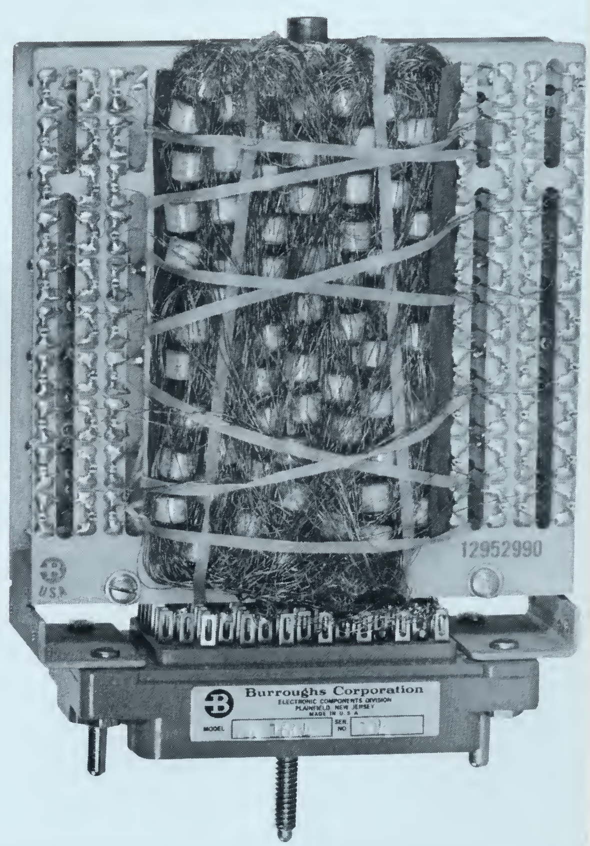
The basic translator unit accepts bit parallel data characters and translates each character to the five separate 7-bit print codes required to form a character.

Recognition and execution of control characters, such as carriage-return, line-feed, end-of-text, end-of-transmission and start-of-message, are additional tasks performed by the TP-4000 translator unit.

A 7-bit data input register, the core rope, a set



Code translator that contributes to the versatility and low cost of the TP-4000 Teleprinter. The translator unit accepts bit parallel data characters and translates each character to five separate 7-bit print codes required to form a character.



The core-rope memory utilized in the TP-4000 translator is a simple and desirable means of implementing fixed logical functions. Fundamentally, the core-rope is a permanent, read-only, associative memory of the magnetic core type.

of seven read amplifiers and the control circuits that make up the essential units. The control circuits, consisting of several binary counting stages and logic gates, exercise the core rope, count out the printout space columns required for each character, and count the number of character positions for each line. With the exception of the core-rope matrix, all of the functions are quite standard. Approximately 60% of the electronics is composed of Motorola MECL integrated circuits.

CORE-ROPE MEMORY FUNDAMENTALS

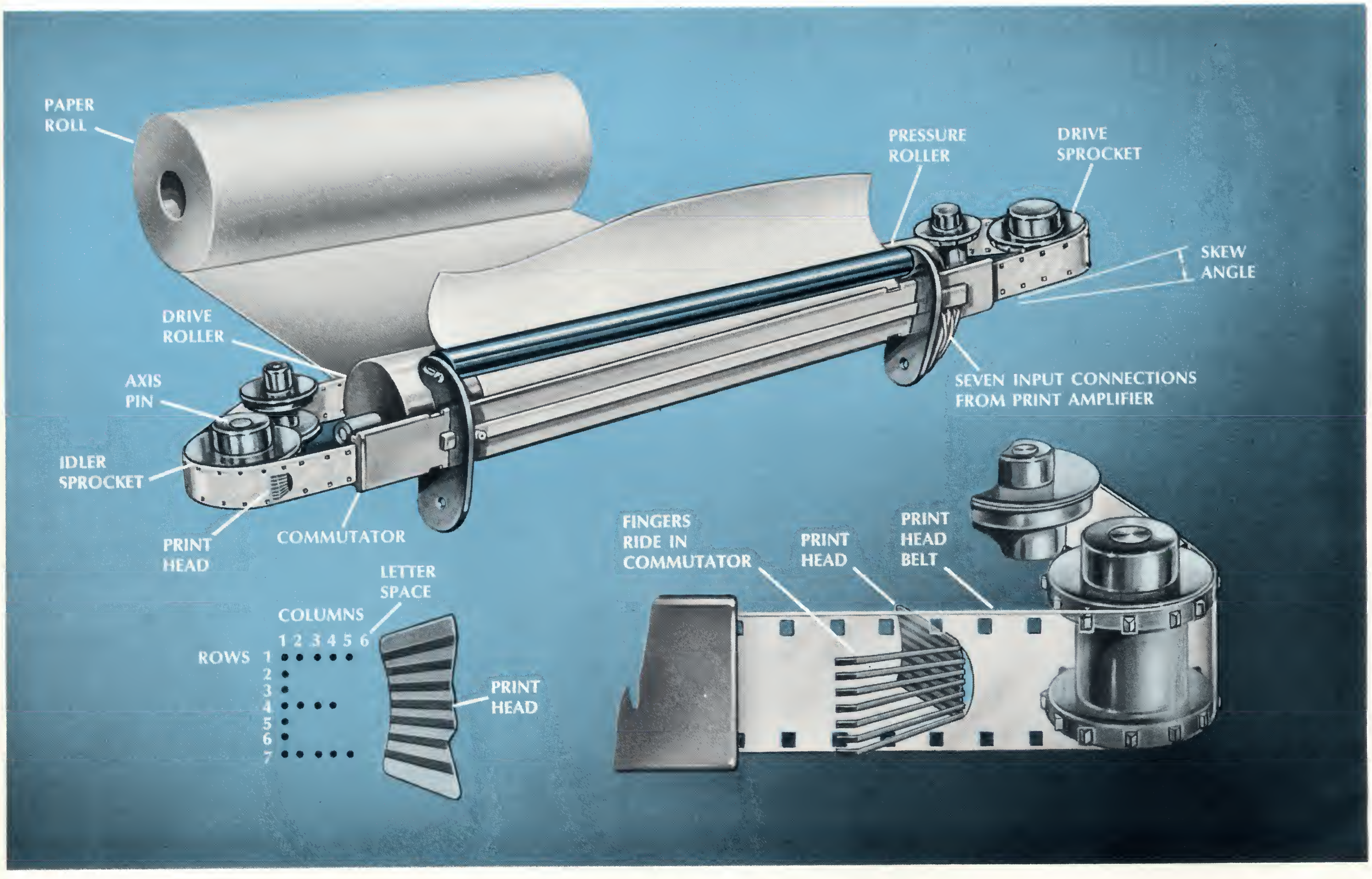
Although the core-rope is a very simple and powerful means of implementing fixed logical functions, it is not generally well known. This is true in spite of the fact that it was introduced almost 20 years ago and has found recent applications in the Apollo and Polaris programs.

The rope is fundamentally a permanent, read-only, associative memory of the magnetic core type. It is permanent to the extent that the information content is fixed by construction, which also explains the read-only characteristic. The associative term means that the output is obtained as a result of a direct association between the input data and the contents of the memory.

Although detailed descriptions of the core rope principles are provided in the literature,[4, 5, 6, 7, 8] Figures 2, 3, and 4 and the following are presented to provide continuity and ease of understanding.

Organizational—A rope memory can be organized in either of two basic configurations — one core/bit or one core/word. Each of these configurations holds advantages; the application dictates the choice. It will be shown later that the lower cost one core/word arrangement is clearly the choice for the TP-4000 requirement.

Figure 1. TP-4000 principles of printing. Four print heads mounted on an endless sprocket driven belt provides smooth continuous motion of the print heads and paper supply. This, with the print heads at an incline upward to the right provides a horizontal line of serially printed characters.



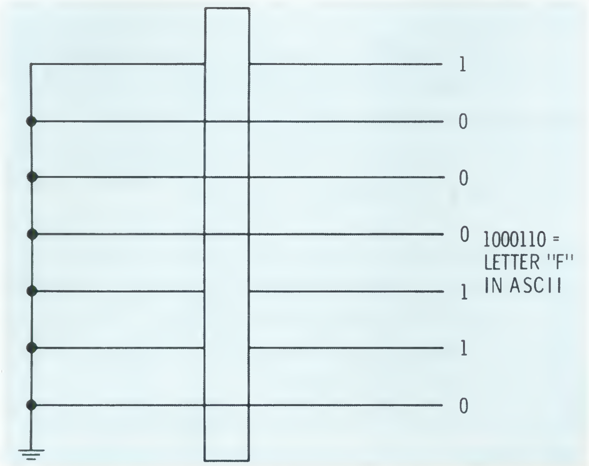


Figure 2. One core storing a 7-bit word. Illustrated is the letter "F" in the American Standard Code for Information Interchange.

Before considering the complete rope, let us begin by examining how one core can be made to store a complete parallel word. Normally, a core is considered to store either a "1" or a "0" bit, depending on whether it is in a positive or negative remanent state. The remanent state is determined by the direction and magnitude of the last pulse of current flowing through a drive line. The information stored by a core is detected by a sense line threading the core. Application of a negative pulse to a core in the positive remanent state will switch the core and generate an output signal on the sense line, which is interpreted as a "1". Likewise, a core in the negative remanent state will produce on the sense line only a small noise signal, which is interpreted as a "0".

Suppose, for example, that a core is always switched from, and then set back to, the positive remanent state. All sense lines threading that core will then produce a "1". Whereas any sense lines bypassing the core will have to produce a "0". A core with seven sense lines threaded in the fashion shown in Figure 2 will, therefore, always produce the 7-bit parallel word 1000110 — the letter "F" in the American Standard Code for Information Interchange (ASCII). This can be extended to provide one additional core for each character in the code. Hence, if one code is used to select the cores, it can be translated to the code stored by the manner in which the sense lines thread the cores.

Core Selection—The power of the core rope as a logical device begins to show itself when we consider the problem of selecting the cores. Inspection of Figure 3 reveals that the cores are selected according to the manner in which the drive lines thread the cores. The selected core is not threaded by any of the enabled (energized) inhibit lines, while every other core is threaded by at least one of the enabled inhibit lines. The drive lines are referred to as inhibit lines because of their negating effect upon all except the selected core. The inhibit lines consist of a direct and a complement line for each bit in the input character code. Each core is also threaded by a common set and reset line. Initially, all cores are in the same remanent state. The inhibit and set current are of equal but opposite polarity. The inhibit current is held constant during any given character period while the set current is applied as a pulse. The reset pulse, applied after the set pulse has terminated, resets the selected core. The output of the sense lines are sampled during the reset period.

So far we have described a device, which in the general sense, requires only 2^n cores, 2^n inhibit, a set, a reset and k sense lines to translate an n-bit code to a k-bit code. In the examples provided by Figures 2 and 3, $n = 3$ and $k = 7$. Note, however, that although the rope requires one core per character translated, it need not provide cores for unused character, nor must the cores be placed in any particular order. Hence, the TP-4000 accepts a 7-bit input and, with a minimum of 64 cores, provides options for up to 128 characters.

Thirty-Five Dot Matrix—Since the standard 35-dot matrix character requires five columns of seven dots, the core rope for the Motorola teleprinter must provide five sequential sets of seven pulses. This can be accomplished several ways, two of which are straightforward. One is to use five times as many cores as the number of characters to be translated and arrange the inhibit lines to select one core in each of the five groups. Although all five groups share a common set line and seven sense lines, each group has a separate reset. As the selected core in each group is sequentially reset, the sense lines will provide the required pattern. The arrangement selected for the TP-4000 makes use of only one core for each character, but requires five sets of seven sense lines. Each set is sequentially selected by means of diode gating, as shown in Figure 4, and combined to feed one common set of sense amplifiers. This arrangement requires that the selected core be set and reset five times for each character. Since both arrangements provide comparable performance, the selection for the TP-4000 was determined by the lower cost and better signal-to-noise ratio of the one-core-per-character arrangement. Note that in this arrangement, each core is actually providing five 7-bit words or one 35-bit word, depending on the point of view.

The combining logic and differential sense am-

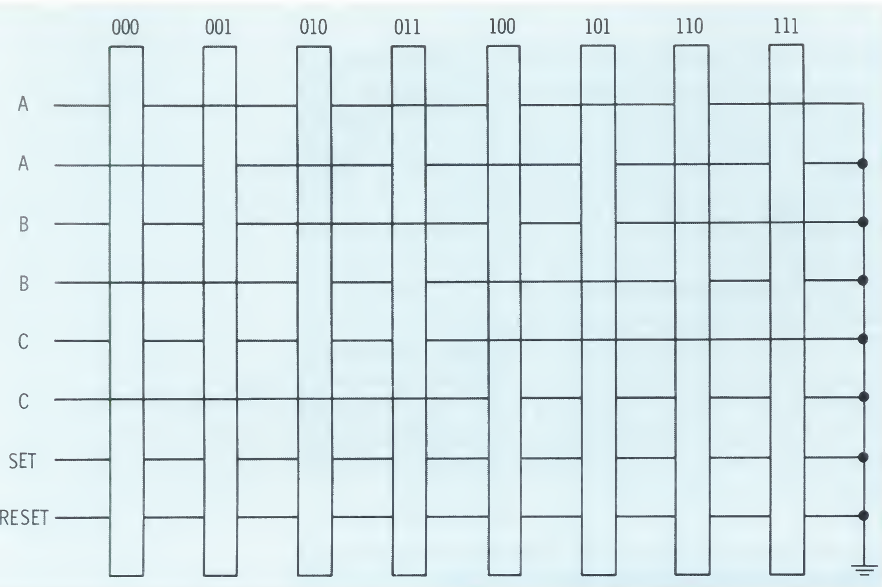
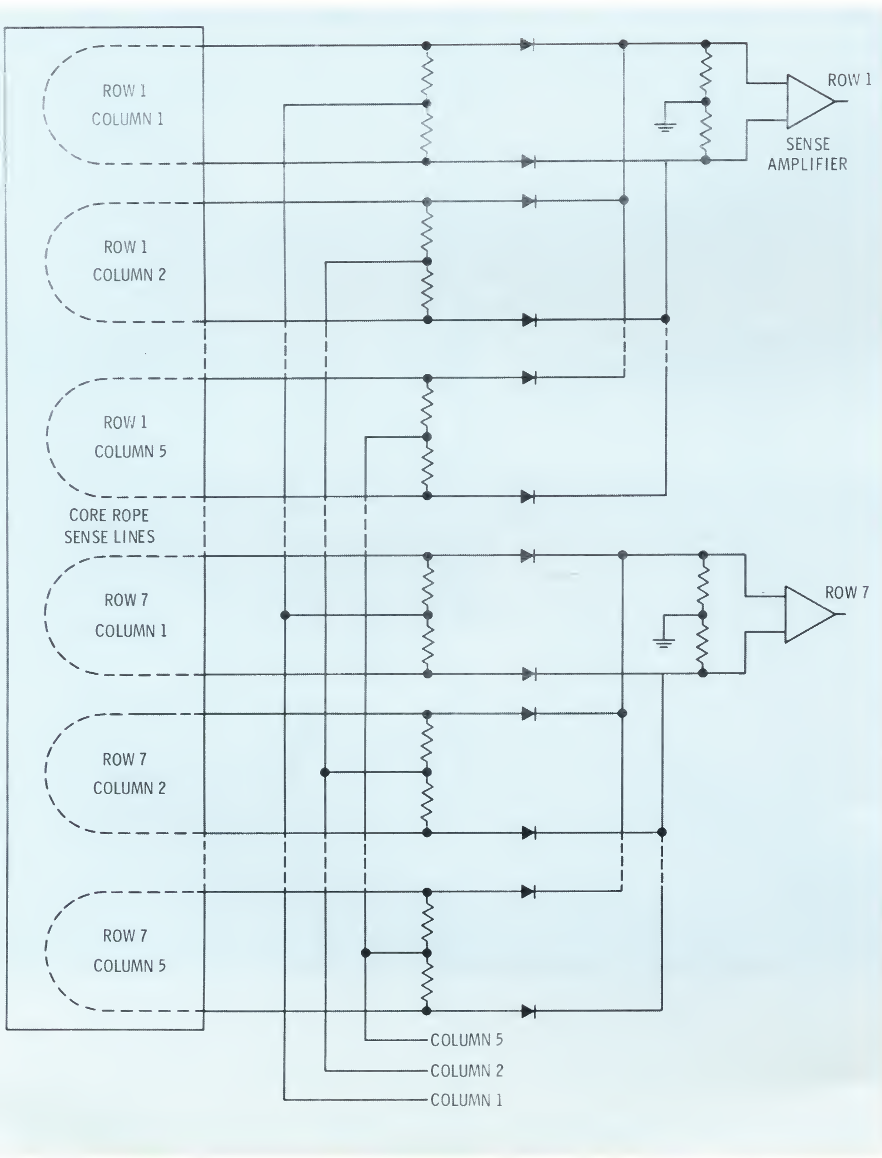


Figure 3. Core selection by inhibit logic. The cores are selected according to the manner in which the drive lines thread the cores.

Figure 4. Column selection of the sense by diode gating. The TP-4000 Teleprinter uses only one core for each character; however, it requires five sets of seven sense lines. Each set is sequentially selected by the diode gating.



plifiers are required because the pulses received from the sense lines are bipolar.

CORE-ROPE FLEXIBILITY DEMONSTRATED Now that we have satisfied the basic requirements of the teleprinter, let us see how the flexibility of the core rope makes it possible to offer a number of other optional data processing functions.

Error Detection—A parity check can be performed on the input data character by threading or not threading the corresponding cores with a separate sense line. The output of this sense line is compared with the parity bit of the input data to determine the validity of the character. Although this is not an advantage if the data is received bit serial, it is a great improvement over other methods if the data is presented bit parallel.

Variation of Input Codes—Considerable headway has been made towards standardizing the codes used for interchange of information with the adoption of ASCII. However, for some time there will remain the problem of integrating established business machines into data communication networks which are not only growing within but are expanding to interconnect through switching centers. Therefore, data terminals capable of accepting a variety of codes hold a decided advantage when considered for varied and universal applications.

The core rope makes it possible for the TP-4000 to offer a very low cost option which provides for the acceptance of a variety of input codes. If two codes have equal repertoires (or mutual portions), either code can be used by simply providing a separate set of inhibit lines and a 14-pole multiple throw switch to select them. This arrangement permits different codes to access the same core, which stores a given character. The only limitations on the number of codes thus accommodated are such practical matters as: the number of wires that can be threaded through the cores, restrictions on the rope connector pins, or the number of switch throws.

Very often one code requires a character not represented in one of the other codes. The rope also takes care of this situation by taking advantage of the fact that the position of a core can be completely arbitrary. A core is added for each character not included in the mutual set of characters. All of the inhibit lines representing codes not using the special character thread the added core. Thus, by adding extra cores and effectively negating undesired characters in the repertoires of other codes, the rope performs this useful and

versatile translation of codes without requiring a change in circuitry, with the exception of the switch. If the translator provides the optional parity check, a separate parity sense line is required for each code. A pair of extra poles on the code selector switch selects the appropriate sense line in such cases.

Variation of Output Codes — Many data processing operations require local and remote input and/or output terminals. Often, these various terminals — displays, printers, keyboards, magnetic and paper tape units, punched card readers and punches, etc. — accept or generate codes foreign to one another as well as to the computer.

Through its code translating power, the TP-4000 printing terminal provides options which serve as the interface between the computer and various other terminal devices, or between terminals themselves.

Suppose a likely situation where a UNIVAC computer transmits data via telephone lines to a remote data center where one of the functions is the magnetic tape recording of the data for off line processing on a Honeywell computer. It is desired that a hard copy of the transmitted data be available for checking before committing it to the computer. The TP-4000 can perform the real time translation between the UNIVAC and Honeywell computers as well as produce the hard copy as fast as the data can be transmitted. The TP-4000 can, in principle, produce several other output codes by time sharing the core rope.

Increased Dot Density — Occasions arise where the 35 dots provided by the standard 7x5 dot matrix are not sufficient for reason of print quality or character shapes. By increasing the number of columns from 5 to 7, a total of 49 dots are made available. If the overall character size is held fixed, the dots practically touch each other, thus improving the print quality and permitting a greater variety of characters.

The core rope makes this option possible with only a slight added expense. Two sets of seven sense lines and two column selection gates are all that is added.

Keyboard Input — The keyboard is the universal device for generation of digital data. There are a variety of keyboards designed to satisfy operational and technical requirements. However, all keyboards can be classified into two groups — those that provide one of the data codes and those that simply provide a signal from each key.

The output of keyboards providing codes can be entered through a set of inhibit lines in the fashion previously described for various input codes. Efforts are currently underway to provide TP-4000 compatibility with both type keyboards.

A slightly different method may be used when the keyboard provides a contact closure for each key. In this case, each core may be selected by a separate set line connected to the associated key.

CORE-ROPE ADVANTAGES SUMMARIZED

The primary advantages the core rope holds over its closest competitor, the diode matrix, is one of lower cost. Further advantages are provided by its smaller size, less power consumption, less heat dissipation and greater flexibility. Even with the great strides made by integrated circuits in reducing cost and size, it is pretty tough to beat the ease and efficiency of threading a wire through a core to implement a logical function. This is especially so when it is possible to thread 200 or so wires. Not only is the core rope itself less costly, it also requires only simple, low cost interface and control circuits. As used in the standard Motorola teleprinter, the rope requires only one dc current driver per inhibit line, one pulse current driver for each of the set and reset lines, seven sense amplifiers and the diode logic for the selection of the columns.

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